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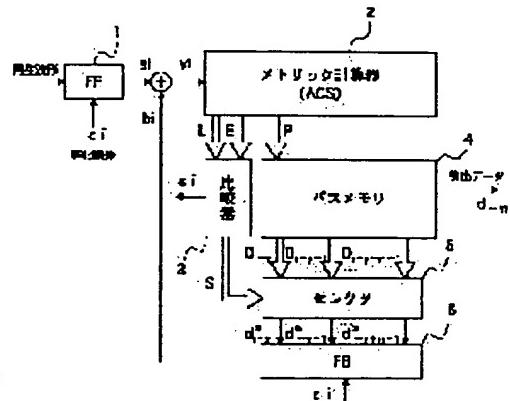
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## (54) INFORMATION REPRODUCING DEVICE USING FEEDBACK FILTER

### (57)Abstract:

**PROBLEM TO BE SOLVED:** To improve the error rate by selecting a data stream corresponding to a path providing a minimum path metric on the basis of a state transition diagram introduced from an output of an impulse response waveform and a depth of a tree so as to obtain a compensation value for equalization.

**SOLUTION:** A metric computing device 2 outputs an equivalent error E, a path metric L of a survival path and a survival path P corresponding to each state on the basis of a state transition diagram. A comparator 3 outputs a path state numbers providing a minimum value to the path metric L and an equivalent error  $\epsilon$  corresponding to a most probable path. A selector 5 uses the state number S to select one of a plurality of data streams D corresponding to the survival path P stored in a path memory 4 and to output a tentatively detected data stream  $d^*$ . A feedback filter 6 obtains and outputs a compensation value to equalize a trailing edge of an impulse response of an output of a feedforward filter 1 to '0' on the basis of the tentatively detected data stream  $d^*$ .



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## DETAILED DESCRIPTION

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### [Detailed Description of the Invention]

#### [0001]

[Field of the Invention] This invention relates to the information regenerative apparatus which equipped data detection with the description especially about the information regenerative apparatus which reproduces the digital information recorded on the magnetic disk, the magnetic tape, the optical disk, etc.

#### [0002]

[Description of the Prior Art] PRML (Partial Response Maximum Likelihood) which combined the partial response method and the maximum-likelihood-detection method as the record data playback approach in digital storage regenerative apparatus, such as a magnetic disk drive and an optical disk, -- law is used. Since it furthermore corresponds to high recording density-ization in recent years, in magnetic recording, the method which combined the modulation technique which can extend the distance between the minimum signs to EEPRL4 method which is the high order PRML method is proposed.

(Jaekyun Moon and Barrett Brickner, "Maximum TransitionRun Codes for Data Storage Systems", IEEE Transactions on Magnetics, vol.32, no.5, and Sept.1996 reference ).

[0003] Moreover, apart from the PRML method, the RAM-DFE (Decision Feedback Equalizer) method and the FDTTS/DF (FixedDelay Tree Search/Decision Feedback) method are also examined as a detector using a feedback filter.

[0004] To the maximum-likelihood-detection method time amount until data are identified becomes unfixed, the FDTTS/DF method restricts path length, is the approach of choosing the smallest pass metric with the limited path length, and tends to correspond to high recording density-ization which this mentioned above.

[0005] Drawing 11 is the block diagram showing the configuration of the equipment by the FDTTS/DF method.

[0006] After a playback wave is set to  $a_i$  ( $i$  is time of day) by passing along the feedforward filter 1101, it is inputted into the FDTTS detector 1111, being used as  $y_i$  through an adder. Although FDTTS detector 1111 output  $d_i$ -gamma +1 is used as detection data, it is inputted into the delay element 11071 at coincidence. Two or more delay elements are prepared, and 11071, 11072, --, 1107n are connected serially, and it is outputted to the feedback filter (FB) 6 as output  $d_i$ -gamma [ of each n delay element ],  $d_i$ -gamma -1, --, data stream D corresponding to [ to this time i ] each condition at  $i$ -gamma to the  $i$ -gamma+n-1 time in  $d_i$ -gamma-n +1.

[0007]  $b_i$  which is feedback filter 1106 output is inputted into the above-mentioned adder, is added with feedforward filter 1101 output  $a_i$ , and is set to  $y_i$ .

[0008] This conventional example is outputted in quest of delay \*\*\*\* data in the FDTTS detector 1111 at the gamma-1 (gamma is the tree depth) time.

[0009] Each of drawing 12 and drawing 13 is drawing showing the judgment approach of FDTTS, and an impulse response.

[0010] An impulse response is a response to record data "1." In magnetic recording, the dipulse which are two continuous solitary waves which the polarity reversed as a playback wave is supported.

Drawing 12 and drawing 13 are the examples of the tree depth gamma= 2. As shown in drawing 12 , in i time, it compares in quest of branch metric and pass metric to four pass (tree), and the pass which gives smallest pass metric is determined. And it outputs as judgment data which decided the data at the i-gamma +1 time in the pass.

[0011] As an input value [ as opposed to the feedback filter 1106 for the detection data stream before i-gamma +1 time called for as mentioned above ], wave compensation at the following i+the 1 time is performed.

[0012] Drawing 13 is the example of an impulse response wave. With the feedforward filter 1101, the output value in an identification point is set to "1", and the former output value is equalized in "0" rather than it. Moreover, identification henceforth of is carried out to "0" with the feedback filter 1106 from gamma bit delay \*\*\*\* from the identification point. Thereby, an identification wave will be expressed with the superposition of the output value (1 and a) of left-behind gamma bit (here 2 bits), and metric count and data detection are performed according to the judgment approach shown in drawing 12 .

[0013]

[Problem(s) to be Solved by the Invention] the FDTS/DF method -- data detection -- FDTS -- law is used. This approach restricts path length, and since it is what asks for pass metric from the limited pass, an error rate property may get worse rather than a maximum-likelihood-detection method.

[0014] Moreover, when it is going to use a maximum-likelihood-detection method, the feedback loop cannot be operated within the time amount (clock) restricted from time amount until data are identified being unfixed, and it being less than the delay by which detection data were restricted, and being unable to ask.

[0015] This invention is made in view of the trouble which a Prior art which was mentioned above has, the feedback loop can be operated in the amount of delay decided while using the maximum-likelihood-detection method, and it aims at realizing the information regenerative apparatus using the highly precise feedback filter with which the error rate has been improved.

[0016]

[Means for Solving the Problem] The information regenerative apparatus using the feedback filter by this invention The feedforward filter which performs identification of the first transition section of the impulse response of a playback wave, sets the output value in an identification point to "1", and sets the output value before it to "0". The feedback filter with which the trailing-edge section after tree depth gamma bit delay \*\*\*\*\* is compensated from said identification point, From the identification wave which said feedforward filter output and the feedback filter output piled up The identification error [ as opposed to each identification reference level value based on the state transition diagram led from the wave output of tree depth gamma and an impulse response ] E The metric calculator which chooses the pass with which it asks for branch metric to each branch, and pass metric, pass metric to each condition is compared, and pass metric serves as min as survival pass to the condition, Input the survival pass chosen by said metric calculator, and this time i is received. The pass memory to which n data of i-gamma to i-gamma+n-1 time output the value of the last stage as data stream D corresponding to each condition, and detection data, The comparator which asks for the pass with which pass metric serves as the minimum value out of the survival pass to each condition searched for by said metric calculator, The selector which inputs data stream D which said pass memory outputs, chooses the data stream corresponding to the pass which gives minimum pass metric called for in said comparator, and is outputted to said feedback filter, It provides and said feedback filter is characterized by calculating the amount of compensation for identification based on the data stream chosen in said selector.

[0017] In this case, it is good also as having the delay element which is made into what has pass

memory length shorter than the number of input data of a feedback filter, holds the detection data which said pass memory outputs, and is outputted to a feedback filter.

[0018] Also in which [ above ] case, a selector is good also as performing adaptive equalization of a feedforward filter and a feedback filter using the identification error which chose the identification error corresponding to the pass used as minimum pass metric, and was this chosen out of the identification error corresponding to each survival pass.

[0019] Moreover, said feedback filter and a metric calculator set tree depth gamma to 2, and a metric calculator is good also as making the state transition diagram of two conditions correspond to the playback wave which said feedforward filter output and the feedback filter output piled up, and performing maximum likelihood detection.

[0020] Moreover, said feedback filter and a metric calculator set tree depth gamma to 3, and a metric calculator is good also as making the state transition diagram of four conditions correspond to the playback wave which said feedforward filter output and the feedback filter output piled up, and performing maximum likelihood detection.

[0021] Furthermore, said feedback filter and a metric calculator set tree depth gamma to 4, and a metric calculator is good also as making the state transition diagram of eight conditions correspond to the playback wave which said feedforward filter output and the feedback filter output piled up, and performing maximum likelihood detection.

[0022] The information playback approach using the feedback filter of this invention Perform identification of the first transition section of the impulse response of a playback wave, and the output value in an identification point is set to "1." The 1st step which compensates the trailing-edge section after tree depth gamma bit delay \*\*\*\*\* from an identification point, and is made into an identification wave while setting the output value before it to "0", The identification error [ as opposed to each identification reference level value based on the state transition diagram led by the wave output of tree depth gamma and an impulse response from said identification wave ] E The 2nd step which chooses the pass with which it asks for branch metric to each branch, and pass metric, pass metric to each condition is compared, and pass metric serves as min as survival pass to the condition, This time i is received based on the survival pass chosen at said 2nd step. The 3rd step which generates n data stream D corresponding to each condition of i-gamma to i-gamma+n-1 time by which the data of the last stage are used as detection data. The 4th step which asks for the pass with which pass metric serves as the minimum value out of the survival pass to each condition searched for at said 2nd step, The 5th step which chooses the data stream corresponding to the pass which gives minimum pass metric called for at said 4th step based on n data stream D generated at said 3rd step, It is characterized by having the 6th step which calculates the amount of compensation for the identification performed at said 1st step based on the data stream chosen in said selector.

[0023] Although pass metric count is closed even by tree depth gamma and minimum pass metric is called for in a "operation" FDTS detector, maximum likelihood detection is performed like a PRML method in this invention.

[0024] In this invention, based on the state transition diagram obtained from a gamma value and an impulse response in a metric calculator, branch metric and pass metric are calculated first, and the survival pass to each condition is determined. However, like a general PRML method, an integral value does not become, but criterion level is a real number value, and can be given to arbitration. Pass memory is the same configuration as a general PRML method, and can perform maximum likelihood detection.

[0025] In order to perform waveform equalization, a feedforward filter and a feedback filter are used. Like the FDTS/DF method, with a feedforward filter, identification of the first transition section of an impulse response is performed, and the output value before it is set to "0" for the output value in an identification point as "1." On the other hand, the feedback filter is compensating the trailing-edge section after gamma bit delay \*\*\*\*\* from the identification point.

[0026] The above waveform-equalization actuation is the same as the FDTS/DF method. The detection value corresponding to the probable pass at present is used for the input value over the feedback filter in this invention as a temporary detection data stream not from a FDTS detection result but from two or more detection data streams recorded on pass memory. This temporary detection data stream is a detection data stream corresponding to that pass, when it asks for the pass which compares pass metric of the survival pass corresponding to each condition, and gives minimum pass metric.

[0027] If the above-mentioned actuation is summarized, the state transition diagram which is to the base of maximum likelihood detection will be determined in a metric calculator from a gamma value and an impulse response wave, and will be recorded on pass memory. A comparator calculates the pass metric minimum value corresponding to two or more survival pass recorded on pass memory. A selector chooses the probable data stream (data stream corresponding to the pass of pass metric min) at present from data stream D of pass memory as temporary detection data by the pass metric minimum value calculated by the comparator. Selected temporary detection data are inputted into a feedback filter. Compensation of the first transition section to an impulse response and the trailing-edge section is performed using this feedback filter and a feedforward filter.

[0028] As mentioned above, in this invention, since it replaced with the FDTS detecting method used by the FDTS/DF method and the maximum-likelihood-detection method (the Viterbi detecting method) was used, the error rate has been improved. Moreover, by using the probable data stream at present as temporary detection data from the data stream recorded on pass memory, feedback actuation can be performed in the decided amount of delay, and it has become a highly precise detector.

[0029]

[Embodiment of the Invention] Next, the example of this invention is explained with reference to a drawing.

[0030] Drawing 1 is the block diagram showing the important section configuration of the information regenerative apparatus using the feedback filter by this invention, and shows the configuration of the part which generates detection data from the playback wave acquired from the reproducing head which is a detector.

[0031] In the data detecting element which is a FDTS/DF method, this example is replaced with a FDTS detector and consists of the metric calculator (ACS) 2 used by a PRML method etc., the feedforward filter (FF) 1 prepared using the pass memory 4 and a comparator 3, a selector, and a feedback filter 6.

[0032] the wave from which identification of the first transition section is carried out to "0" from the identification point of an impulse response wave with the feedforward filter (FF) 1, and the playback wave acquired from the reproducing head (un-illustrating) starts to "1" in an identification point -- it is outputted as  $a_i$  ( $i$  is time of day). It is outputted to the metric calculator (ACS circuit) 2, the output  $a_i$  of this feedforward filter 1 being added with the output  $b_i$  of the feedback filter (FB) 6, and being used as  $y_i$ . By adding the output  $a_i$  of the feedforward filter 1 with the output  $b_i$  of the feedback filter 6, the trailing-edge section from the number of bits (tree depth gamma) which started and was defined from the location serves as a wave by which identification was carried out "0." The definition of tree depth gamma is the same as that of the definition in a FDTS/DF method, and the number of bits to the location which is the feedback filter 6 and is equalized from an identification point is shown.

[0033] By the metric calculator 2, it asks for the identification error  $E$  over each identification reference level value, branch metric to each branch, and pass metric from Input  $y_i$  (identification wave) based on the state transition diagram led from the wave output of tree depth gamma and an impulse response. And pass metric to each condition is compared and the pass with which pass metric serves as min is chosen as survival pass to the condition.

[0034] The metric calculator 2 performs the above actuation, outputs pass metric  $L$  of the identification error  $E$  corresponding to each condition, and survival pass to a comparator 3, and outputs the survival pass  $P$  (selection result) to the pass memory 4.

[0035] In a comparator 3, the minimum value of the survival pass to each condition pass metric [ L ] is calculated, and identification error  $\epsilon_{\text{pi}}$  corresponding to the probable pass is chosen from the state number S and identification error E, and it outputs to the feedback filter 6 at the same time it outputs the state number S corresponding to the pass which gives the minimum value to a selector 5.

[0036] In a selector 5, one is chosen from multiple-data-stream D corresponding to [ survive and ] pass recorded on pass memory using the selected state number S, and temporary detection data stream d\* is outputted. Temporary judging data stream d\* is gamma bit delay \*\*\*\*\* earlier data train from this time i, and outputs the trailing-edge section (from a standup to gamma bit delay \*\*\*\*\* (or before)) of the impulse response of FF output to "0" in quest of the compensation value for considering as identification based on this d\* in FB. On the other hand, the last stage output of pass memory is used as final detection data d, without using temporary detection data.

[0037] Next, actuation of this example is explained.

[0038] First, the principle of operation of the feedforward filter 1 in drawing 1 and the feedback filter 6 is explained. The impulse response wave corresponding to some gamma values is shown in drawing 2. "1" of record data is made to correspond to the dipulse (continuous wave form of two solitary waves where polarities differ) in a playback wave here, supposing a magnetic recording medium. That is, it changes to record data (1-D), and the solitary wave is made to correspond to the point that translation data is set to "1." gamma is similarly defined as the tree depth in FDTS/DF, and from an identification point, gamma bit is the feedback filter 6 and it is used for maximum likelihood detection, without carrying out identification.

[0039] Drawing 2 (a) is [ gamma= 3 and drawing 2 (c) of gamma= 2 and drawing 2 (b) ] the examples of an identification wave (impulse response) of gamma= 4.

[0040] In each impulse response wave, the feedforward filter (FF) 1 performs identification to the first transition section from the time (identification point) of going up from 0 to +1 first, and all are equalized in "0."

[0041] The wave output values a, b, and c after the identification point shown in drawing 2 are any value, and it is also possible that identification of it is carried out with the feedforward filter 1 since the value of these a, b, and c to determine in consideration of a property, an error rate, etc. of a playback wave is determined by the feedforward filter 1, if a playback wave does not change.

[0042] On the other hand, the feedback filter (FB) 6 performs identification to the trailing-edge section after gamma time from an identification point, and all are equalized in "0." As long as there is no judgment error, the feedback filter 6 is not influenced of a noise, in order to compensate based on the judgment result in an identification point. The impulse response wave by which identification was carried out is acquired for all the bits excluding a part for gamma bit from the identification point by the above "0."

[0043] The identification wave y acquired as mentioned above is inputted into the metric calculator (ACS circuit) 2 of the maximum \*\* (Viterbi) detector shown in drawing 1.

[0044] The state transition diagram which serves as a base for performing metric count of maximum likelihood detection in this example at drawing 3 is shown. Drawing 3 (a) is [ gamma= 3 and drawing 3 (c) of gamma= 2 and drawing 3 (b) ] the examples of gamma= 4. These state transition diagrams are constituted based on the impulse response wave shown in drawing 2, and the value shown in each branch expresses detection data and an identification reference value. Based on such a state transition diagram, from a difference (identification error E) with an identification reference value, it asks for branch metric and pass metric, and the survival pass to each condition is determined. Although it survives to pass memory and Pass P is only outputted in the conventional ACS circuit, pass metric L to each survival pass and the identification error E are outputted to coincidence by the metric calculator (ACS circuit) 2 in this example.

[0045] Outputted pass metric L and the identification error E are inputted into the comparator 3 shown in drawing 1. In the comparator 3, a comparison pass metric [ corresponding to each condition / L ] is

performed, and it is asking for the state number S corresponding to the pass which gives the minimum pass metric value. Moreover, with this state number S, the value which corresponds from the identification error E is chosen, and it is outputting as identification error epsilon. feedforward -- a filter -- (FF) -- one -- and -- feedback -- a filter -- (FB) -- six -- immobilization -- a parameter -- a filter -- it is -- a case -- identification -- an error -- epsilon -- i -- being unnecessary -- although -- adaptive equalization -- carrying out -- a case -- this identification error epsilon -- using -- the parameter of the feedforward filter (FF) 1 and the feedback filter (FB) 6 -- receiving -- adaptive equalization -- carrying out -- serially -- it can change . As it is made in agreement with the value which the adaptive equalization of the feedforward filter (FF) 1 set the first transition section of an impulse response to "0", and showed the wave output value of gamma bit by drawing 2 from the identification point, it is changing a parameter, and the adaptive equalization of the feedback filter (FB) 6 is changing a parameter so that the trailing-edge section of an impulse response may be set to "0."

[0046] The configuration of the pass memory 4 is fundamentally [ as the pass memory in the conventional PRML method ] the same. Changed parts are that the value in the first rank is changed based on a state transition diagram, and that n of i-gamma to i-gamma+n-1 time are outputted as an input candidate to the feedback filter (FB) 6 to this time i as data stream D corresponding to each condition in the contents of the pass memory 4. the first rank of the pass memory 4 -- by modification of a value, since the selector of the first rank becomes meaningless, the delay element and selector of the first rank can also be deleted.

[0047] In a selector 5, probable temporary judging data stream d\* is chosen at present from such data stream D by the state number S. The feedback filter (FB) 6 outputs the compensation value for waveform equalization (compensation of the trailing-edge section) based on this data stream d\*. On the other hand, the detection data d as a detector of this example are outputted not from above-mentioned temporary detection data d\* but from the last stage of pass memory. Therefore, sufficiently long pass memory is taken, and if pass is completed, a maximum-likelihood-determination result will be obtained.

[0048] In this example, a gamma value can set up two or more values. Moreover, it sets up beforehand and the wave output value after the identification point of an impulse response can also be maintained by performing adaptive equalization to the feedforward filter (FF) 1. What is necessary is just to create the state transition diagram for maximum likelihood detection with these values.

[0049] Next, the case of the tree depth gamma= 3 is explained more concretely as an example about actuation of the example mentioned above.

[0050] Drawing 4 is drawing showing the identification process of a playback wave corresponding to record data "1" (identification process of an impulse response), and explains an identification process in detail using drawing 4 .

[0051] A continuous-line wave is the impulse response of the feedforward filter (FF) 1. With the feedforward filter (FF) 1, the time (identification point) of an output value starting is set to "1", and the first transition section is equalized in 0 from there. At this time, identification about the trailing-edge section is not performed rather than an identification point. Since the feedback filter (FB) 6 in this example is outputting the compensation value by the delay of gamma bit, it can be compensated from an identification point to gamma bit delay \*\*\*\*\*. It is an identification wave after compensation with the feedback filter (FB) 6 that each arrow head at the time shows the amount of compensation, and is shown by the dotted line. The value of a and b is determined by arbitrary playback wave-like properties etc. Moreover, the gestalt of the feedforward filter (FF) 1 and the feedback filter (FB) 6 is also arbitrary.

[0052] Since the feedforward filter (FF) 1 just equalizes a playback wave like the continuous line of drawing 4 , an analog filter, its transversal filter, etc. are usable. Since the feedback filter (FB) 6 just outputs the compensation value for identification from a detection data stream, it can use a transversal

filter and a RAM table.

[0053] Metric count is [ that what is necessary is just to carry out based on the state transition diagram shown in drawing 3 (b) ] fundamentally [ as the conventional ACS circuit ] the same. A difference is the point of outputting pass metric value L0-3 corresponding to four survival pass, and identification difference E0-3 in addition to survival pass P0-3 corresponding to each condition.

[0054] The configuration of the state number S which asks for smallest pass metric and corresponds to drawing 5 from these pass metric L0-3, and the comparator 3 which searches for the identification error epsilon for adaptive equalization is shown. The comparator 3 consists of a comparator 10 and a selector (S) 9. A comparator 10 outputs the state number S which compares four pass metric L0-3 and gives the minimum value. The selector (S) 9 is outputting Es as identification error epsilon from four input values (identification error E0-3) based on a state number S.

[0055] The configuration of the pass memory 4 and a selector 5 is shown in drawing 6 . The configuration of pass memory is fundamentally [ as the conventional PRML method ] the same. However, if a state transition diagram 3 (b) is followed, since the selector of the first rank will serve as selection from the same value, the delay element and selector of the first rank are omitted. Moreover, corresponding to the several n input data bit of the feedback filter (FB) 6, n steps of data stream D is outputted outside. The data D from each stage (at each time) are four corresponding to a condition, and are judgment data corresponding to the survival pass of each condition.

[0056] In the selector 5, the data in each time are chosen with a state number S, and probable temporary judging data stream d\* is outputted at present. Final detection data are outputted from the back end of the pass memory 4. At this time, when pass memory length is longer than the number of input data of the feedback filter (FB) 6, the configuration shown in drawing 6 may be used, but when short, it is [ that what is necessary is to hold detection data using the delay element and just to input into the feedback filter (FB) 6 ] good also as such a configuration.

[0057] Drawing 7 is drawing for explaining the process in which a temporary judging data stream is determined, and drawing 7 (a) is the example of a trellis diagram. The continuous line shows the survival pass in i time. When such survival pass is called for, data as shown in drawing 7 (b) are recorded on pass memory. If survival pass merges, all the judgment data in the time are in agreement. Here, it has merged at the i-3 time and the detection data before it are decided. When L1 becomes the minimum value among pass metric L0-3 of the survival pass in this time, the data stream corresponding to the condition S1 of having surrounded by the dotted-line frame is chosen, and it is used as an input to the feedback filter (FB) 6.

[0058] By the above, feedback can be hung by the delay of gamma clock like a FDTS/DF method. Drawing 8 shows the identification reference value and branch metric for performing metric count. Based on these formulas, branch metric and pass metric count is performed, and maximum likelihood detection is performed. The constant derived from the identification reference values R and R can reduce the amount of operations by calculating beforehand.

[0059] Next, the 2nd example of this invention is explained with reference to drawing 9 and drawing 10 .

[0060] These make the 1st comparator 3 in an example, pass memory 4, and selector 5 the comparator 903, the pass memory 904, and the selector 905 from which a configuration differs, drawing 9 is drawing showing the configuration of the comparator 903 in the 2nd example of this invention, and drawing 10 of this example is drawing showing the configuration of the pass memory 904 in the 2nd example of this invention, and a selector 905. Since the configuration of those other than these is the same as that of the 1st example, only these configurations are explained.

[0061] The number of clocks required of the operation gestalt shown in drawing 5 and drawing 6 since a signal is transmitted in the feedback loop is only 1 clock. This one clock needs to perform count of an identification wave, branch metric and pass metric count, selection of survival pass, minimum pass metric detection, and selection of temporary detection data, it is necessary to calculate the amount of compensation with the feedback filter 6 (FB) further, and a circuit-burden is very large. Then, in the

2nd example, it makes it possible to increase the number of clocks required since a signal is transmitted in the feedback loop.

[0062] The configuration and actuation of this example are concretely explained with reference to drawing 9 and drawing 10. the comparator 903 of this example -- setting -- a delay element (D) -- 9071 and 9072 are prepared and the delay element (D) 9073 is formed in the pass memory 904. by each of these delay elements (D), 1 bit is delayed, respectively in pass metric L which is the output of the ACS circuit 2, the identification error E, and the selection branch (survival pass) P, instead, 1 bit of data stream D which is an output from the pass memory 904 is shifted, and it is outputted (1:00 point -- bringing forward). By the above, it can have the allowances of one clock in time, and the feedback loop can be calculated. However, by this approach, since the output from a number-of-stages eye with pass memory low 1 bit is used for temporary judging data d\*, precision has fallen.

[0063] What is necessary is to shift the output location of the data D shown in drawing 10 in the number-of-stages direction where pass memory is low, instead just to insert a delay element in somewhere, in order to acquire k bits (clock) time allowances. It is made for the timing of each operation not to shift then. The feedback loop will operate with a 1+k clock by this. Moreover, since the identification error for performing adaptive equalization may also shift from i time, adaptive equalization is also performed according to it. Generally by this approach, the feedback loop can be operated by the delay of gamma-1 bit of maxes.

[0064]

[Effect of the Invention] Since this invention is constituted as explained above, the effectiveness indicated below is done so.

[0065] In the FDTs/DF method, it is effective in the ability to make an error rate improve by replacing with FDTs detection and using the maximum-likelihood-detection method (the Viterbi detecting method) used by the PRML method.

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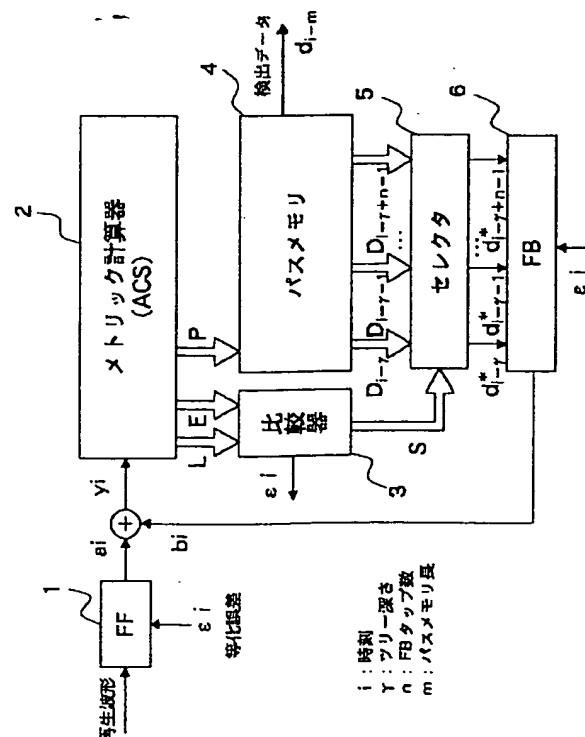
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(54)【発明の名称】 フィードバックフィルタを用いた情報再生装置

(57)【要約】

【課題】 F D T S / D F 法では、データ検出に F D T S 法を用いている。この方法は、バス長を制限して、限られたバスに対してバスメトリックを求めているため最尤検出法よりもエラーレート特性が悪化する可能性がある。最尤検出法を用いると限られた時間(クロック)内でフィードバックループを動作させることができない。

【解決手段】 F D T S 検出器の代わりに、最尤検出器を用いる。さらに、フィードバックループを動作させるために、バスメモリに記録された複数のデータ列から、現時点で最も確からしいデータ列を選択し、仮検出データ列として F B (フィードバックフィルタ) に入力する。この F B と F F (フィードフォワードフィルタ) を用いて再生波形を等化する。最終的な検出データは、バスメモリ最終段出力を用いる。



記録密度化に対応しようとするものである。

【0005】図11はFDTS/DF法による装置の構成を示すブロック図である。

【0006】再生波形はフィードフォワードフィルタ1101を通ることにより $a_i$  ( $i$ は時刻)とされた後に加算器を介して $y_i$ とされてFDTS検出器1111に入力される。FDTS検出器1111出力 $d_{i-\gamma}$ は検出データとされるが、同時に遅延素子1107<sub>n</sub>に入力されている。遅延素子は複数設けられており、1107<sub>1</sub>, 1107<sub>2</sub>, …, 1107<sub>n</sub>がシリアルに接続され、 $n$ 個の遅延素子それぞれの出力 $d_{i-\gamma_1}, d_{i-\gamma_2}, \dots, d_{i-\gamma_n}$ は、現時点 $i$ に対して、 $i-\gamma$ から $i-\gamma+n-1$ 時点の各状態に対応するデータ列Dとして、フィードバックフィルタ(FB)6へ出力されている。

【0007】フィードバックフィルタ1106出力である $b_i$ は上記の加算器に入力され、フィードフォワードフィルタ1101出力 $a_i$ と加算されて $y_i$ とされる。

【0008】本従来例は、FDTS検出器1111において $\gamma-1$  ( $\gamma$ はツリー深さ) 時点遅れた検出データを求めて出力している。

【0009】図12および図13のそれぞれは、FDTSの判定方法およびインパルス応答を示す図である。

【0010】インパルス応答は、記録データ“1”に対する応答である。磁気記録では、再生波形として極性の反転した連続する2つの孤立波であるダイバルスに対応している。図12および図13はツリー深さ $\gamma=2$ の例である。図12に示すように、 $i$ 時点において、4つのバス(ツリー)に対するプランチメトリックとバスメトリックを求めて比較し、最も小さなバスメトリックを与えるバスを決定する。そして、そのバスにおける $i-\gamma+1$ 時点のデータを確定した判定データとして出力する。

【0011】上記のようにして求められた $i-\gamma+1$ 時点以前の検出データ列をフィードバックフィルタ1106に対する入力値として、次の $i+1$ 時点の波形補償を行う。

【0012】図13は、インパルス応答波形の例である。フィードフォワードフィルタ1101により、識別点での出力値を“1”とし、それよりも以前の出力値を“0”に等化している。また識別点から $\gamma$ ビット遅れた点から以降は、フィードバックフィルタ1106により“0”に等化されている。これにより等化波形は、残された $\gamma$ ビット(ここでは2ビット)の出力値(1と0)の重ね合わせで表されることになり、図12に示される判定方法に従ってメトリック計算とデータ検出が行われる。

【0013】

【発明が解決しようとする課題】FDTS/DF法ではデータ検出にFDTS法を用いている。この方法

は、バス長を制限するものであり、限られたバスに対してバスメトリックを求めるものであるため、最尤検出法よりもエラーレート特性が悪化する可能性がある。

【0014】また、最尤検出法を用いようとする場合には、データが同定されるまでの時間が不定であり、検出データを限られた遅延以内で求めることができないことから限られた時間(クロック)内でフィードバックループを動作させることができない。

【0015】本発明は上述したような従来の技術が有する問題点に鑑みてなされたものであって、最尤検出法を用いるとともに決められた遅延量でフィードバックループを動作させることができ、エラーレートが改善された高精度なフィードバックフィルタを用いた情報再生装置を実現することを目的とする。

【0016】

【課題を解決するための手段】本発明によるフィードバックフィルタを用いた情報再生装置は、再生波形のインパルス応答の前縁部の等化を行い、識別点での出力値を“1”とし、それ以前の出力値を“0”とするフィードフォワードフィルタと、前記識別点からツリー深さ $\gamma$ ビット遅れた時点以後の後縁部の補償を行うフィードバックフィルタと、前記フィードフォワードフィルタ出力およびフィードバックフィルタ出力とが重ね合わされた等化波形から、ツリー深さ $\gamma$ とインパルス応答の波形出力から導かれる状態遷移図に基づいて各等化基準レベル値に対する等化誤差E、各プランチに対するプランチメトリック、および、バスメトリックを求め、各状態へのバスメトリックを比較し、バスメトリックが最小となるバスをその状態への生き残りバスとして選択するメトリック計算器と、前記メトリック計算器により選択された生き残りバスを入力し、現時点 $i$ に対して、 $i-\gamma$ から $i-\gamma+n-1$ 時点までの $n$ 個のデータが各状態に対応したデータ列Dおよび検出データとして最終段の値を出力するバスメモリと、前記メトリック計算器にて求められた各状態への生き残りバスの中からバスメトリックが最小値となるバスを求める比較器と、前記バスメモリが出力するデータ列Dを入力し、前記比較器にて求められた最小バスメトリックを与えるバスに対応するデータ列を選択して前記フィードバックフィルタへ出力するセレクタと、を具備し、前記フィードバックフィルタは、前記セレクタにて選択されたデータ列に基づいて等化のための補償量を求める特徴とする。

【0017】この場合、バスメモリ長がフィードバックフィルタの入力データ数よりも短いものとされ、前記バスメモリが出力する検出データを保持してフィードバックフィルタへ出力する遅延素子を有することとしてもよい。

【0018】上記のいずれの場合においても、セレクタは、各生き残りバスに対応する等化誤差の中から、最小バスメトリックとたろバスに対応する等化誤差を選択

タを用いた情報再生装置の要部構成を示すブロック図であり、検出器である再生ヘッドから得られた再生波形から検出データを生成する部分の構成を示している。

【0031】本実施例は、FDTS/DF方式のデータ検出部において、FDTS検出器に代えて、PRML方式などで用いられるメトリック計算器(ACS)2とバスメモリ4を用いたものであり、この他に設けられたフィードフォワードフィルタ(FF)1、比較器3、セレクタおよびフィードバックフィルタ6から構成される。

【0032】再生ヘッド(不図示)から得られた再生波形は、フィードフォワードフィルタ(FF)1によって、インパルス応答波形の識別点より前縁部が“0”に等化されて識別点で“1”に立ち上がる波形 $a_i$ ( $i$ は時刻)として出力される。このフィードフォワードフィルタ1の出力 $a_i$ は、フィードバックフィルタ(FB)6の出力 $b_i$ と加算され、 $y_i$ とされてメトリック計算器(ACS回路)2に出力される。フィードフォワードフィルタ1の出力 $a_i$ はフィードバックフィルタ6の出力 $b_i$ と加算されることによって、立ち上がり位置から定められたビット数(ツリー深さ $\gamma$ )からの後縁部が“0”に等化された波形となる。ツリー深さ $\gamma$ の定義は、FDTS/DF方式における定義と同様であり、識別点からフィードバックフィルタ6で等化する位置までのビット数を示している。

【0033】メトリック計算器2では、ツリー深さ $\gamma$ とインパルス応答の波形出力から導かれる状態遷移図に基づいて、入力 $y_i$ (等化波形)から、各等化基準レベル値に対する等化誤差E、各プランチに対するプランチメトリック、および、バスメトリックを求める。そして各状態へのバスメトリックを比較し、バスメトリックが最小となるバスをその状態への生き残りバスとして選択する。

【0034】メトリック計算器2は以上の動作を行い、各状態に対応する等化誤差Eおよび生き残りバスのバスメトリックLを比較器3へ出力し、生き残りバスP(選択結果)をバスメモリ4へ出力する。

【0035】比較器3では、各状態への生き残りバスのバスメトリックLの最小値を求め、最小値を与えるバスに対応する状態番号Sをセレクタ5へ出力すると同時に、その状態番号Sと等化誤差Eから、最も確からしいバスに対応する等化誤差 $\epsilon_i$ を選択してフィードバックフィルタ6へ出力する。

【0036】セレクタ5では、選択された状態番号Sを用いてバスメモリに記録された生き残りバスに対応する複数のデータ列Dから1つを選択して仮検出データ列d'を出力する。仮判定データ列d'は、現時点*i*から $\gamma$ ビット遅れた時点以前のデータ列であり、FBでは、このd'をもとに、FF出力のインパルス応答の後縁部(立ち上がりから $\gamma$ ビット遅れた時点以前)を“0”に等化とするための補償値を求め出力する。一方、最終的な検

出データdとしては、仮検出データを用いずにバスメモリの最終段出力を用いる。

【0037】次に本実施例の動作について説明する。

【0038】まず、図1におけるフィードフォワードフィルタ1、および、フィードバックフィルタ6の動作原理を説明する。図2にいくつかの $\gamma$ 値に対応するインパルス応答波形を示す。ここでは磁気記録装置を想定し、記録データの“1”を再生波形におけるダイバ尔斯(極性の異なる2つの孤立波の連続波形)に対応させていく。つまり記録データに対して(1-D)変換を行ない、変換データが“±1”となる点に孤立波を対応させている。 $\gamma$ はFDTS/DFにおけるツリー深さと同様に定義され、識別点から $\gamma$ ビットがフィードバックフィルタ6で等化されずに最尤検出に利用される。

【0039】図2(a)は $\gamma=2$ 、図2(b)は $\gamma=3$ 、図2(c)は $\gamma=4$ の等化波形(インパルス応答)の例である。

【0040】それぞれのインパルス応答波形において、最初に0から+1に上がる時点(識別点)から前縁部に対する等化をフィードフォワードフィルタ(FF)1で行ない、すべて“0”に等化している。

【0041】図2に示された識別点以降の波形出力値a、b、cは任意の値であり、再生波形の特性やエラーレートなどを考慮して決定すればよい。これらa、b、cの値は、再生波形が変化しなければ、フィードフォワードフィルタ1によって決定されるので、フィードフォワードフィルタ1によって等化されていると考えることもできる。

【0042】一方、識別点から $\gamma$ 時点以降の後縁部に対する等化は、フィードバックフィルタ(FB)6によって行ない、すべて“0”に等化する。フィードバックフィルタ6は、識別点での判定結果をもとに補償を行なうため、判定誤りがない限りノイズの影響を受けない。以上によって、識別点から $\gamma$ ビット分を除いたすべてのビットが“0”に等化されたインパルス応答波形が得られる。

【0043】上記のようにして得られた等化波形yは、図1に示した最尤(ビタビ)検出器のメトリック計算器(ACS回路)2に入力される。

【0044】図3に、本実施例における、最尤検出のメトリック計算を行なうための基本となる状態遷移図を示す。図3(a)は、 $\gamma=2$ 、図3(b)は、 $\gamma=3$ 、図3(c)は、 $\gamma=4$ の例である。これらの状態遷移図は、図2に示したインパルス応答波形を元に構成されており、各プランチに示された値は、検出データと等化基準値を表している。このような状態遷移図に基づいて、等化基準値との差(等化誤差E)からプランチメトリック、および、バスメトリックを求める、各状態に対する生き残りバスを決定する。従来のACS回路では、バスメモリに対して生き残りバスPを出力しているだけである

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タを状態番号Sによって選択し、現時点で最も確からしい仮判定データ列d'を出力している。最終的な検出データは、バスメモリ4の後端から出力されている。このときバスメモリ長が、フィードバックフィルタ(FB)6の入力データ数よりも長い場合は、図6に示す構成でよいが、短い場合は、遅延素子を用いて検出データを保持しておき、フィードバックフィルタ(FB)6に入力すればよく、このような構成としてもよい。

【0057】図7は仮判定データ列を決定する過程を説明するための図であり、図7(a)は、トレリス線図の例である。i時点での生き残りバスを実線で示している。このような生き残りバスが求められているとき、バスメモリには、図7(b)に示すようなデータが記録されている。生き残りバスがマージすると、その時点での判定データは、すべて一致する。ここでは、i-3時点までマージしており、それ以前の検出データは確定している。現時点での生き残りバスのバスメトリックL<sub>i-3</sub>のうち、最小値となったのがL<sub>i-3</sub>であった場合、点線枠で囲んだ、状態S1に対応するデータ列が選択され、フィードバックフィルタ(FB)6への入力として用いられる。

【0058】以上により、FDTS/DF方式と同様にクロックの遅れでフィードバックを掛けることができる。図8は、メトリック計算を行うための、等化基準値とプランチメトリックを示している。これらの式にもとづいてプランチメトリック、および、バスメトリックの計算を行い最尤検出を行う。等化基準値Rおよび、Rから派生する定数は、あらかじめ計算しておくことによって演算量を減らすことができる。

【0059】次に、本発明の第2の実施例について図9および図10を参照して説明する。

【0060】本実施例は、第1の実施例における比較器3、バスメモリ4およびセレクタ5をこれらとは構成が異なる比較器903、バスメモリ904およびセレクタ905としたものであり、図9は、本発明の第2の実施例における比較器903の構成を示す図であり、図10は本発明の第2の実施例におけるバスメモリ904とセレクタ905の構成を示す図である。これら以外の構成は第1の実施例と同様であるため、これらの構成についてのみ説明する。

【0061】図5および図6に示した実施形態では、フィードバックループを信号が伝わるために必要なクロック数は、わずか1クロックである。この1クロックで、等化波形の計算、プランチメトリックとバスメトリックの計算、生き残りバスの選択、最小バスメトリックの検出、仮検出データの選択を行い、さらにフィードバックフィルタ6(FB)で補償量の計算を行う必要があり、回路的な負担が非常に大きい。そこで、第2の実施例においては、フィードバックループを信号が伝わるために必要なクロック数を増やすことを可能としている。

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【0062】本実施例の構成および動作について、図9および図10を参照して、具体的に説明する。本実施例の比較器903においては、遅延素子(D)907<sub>1</sub>、907<sub>2</sub>が設けられ、バスメモリ904には遅延素子(D)907<sub>3</sub>が設けられている。これらの各遅延素子(D)により、ACS回路2の出力であるバスメトリックL<sub>i</sub>、等化誤差E、選択ブランチ(生き残りバス)Pをそれぞれ1ビット遅延し、代わりに、バスメモリ904からの出力であるデータ列Dを、1ビットずらして(1時点早めて)出力している。以上により、時間的に1クロックの余裕をもってフィードバックループの演算を行うことができる。ただし、この方法では、仮判定データd'は、バスメモリの1ビット低い段数目からの出力を用いているので精度が落ちている。

【0063】kビット(クロック)の時間的余裕を得るために、図10に示したデータDの出力位置をバスメモリの低い段数方向へずらし、その代わりにどこかに遅延素子を挿入すればいい。そのときそれぞれの演算のタイミングがずれないようにする。これによりフィードバックループは、1+kクロックで動作することになる。また適応等化を行うための等化誤差もi時点からずれる可能性があるので適応等化もそれに合わせて行う。この方法では、一般に最大 $\gamma-1$ ビットの遅れでフィードバックループを動作させることができる。

【0064】

【発明の効果】本発明は以上説明したように構成されているので、以下に記載する効果を奏する。

【0065】FDTS/DF法において、FDTS検出に代えて、PRML方式で用いる最尤検出法(ビタビ検出法)を用いることにより、エラーレートを改善させることができる効果がある。

【図面の簡単な説明】

【図1】本発明の検出器の全体構成を示すブロック図

【図2】本発明における、各 $\gamma$ に対するインパルス応答を示す図

【図3】本発明における、各 $\gamma$ に対する状態遷移図

【図4】本発明における、 $\gamma=3$ に対する波形等化法を示す図

【図5】図1の比較器3において、 $\gamma=3$ とした場合の詳しい構成を示す図

【図6】図1のバスメモリ4およびセレクタ5において、 $\gamma=3$ とした場合の詳細な構成を示す図

【図7】図6のバスメモリ4およびセレクタ5の動作の例を示す図

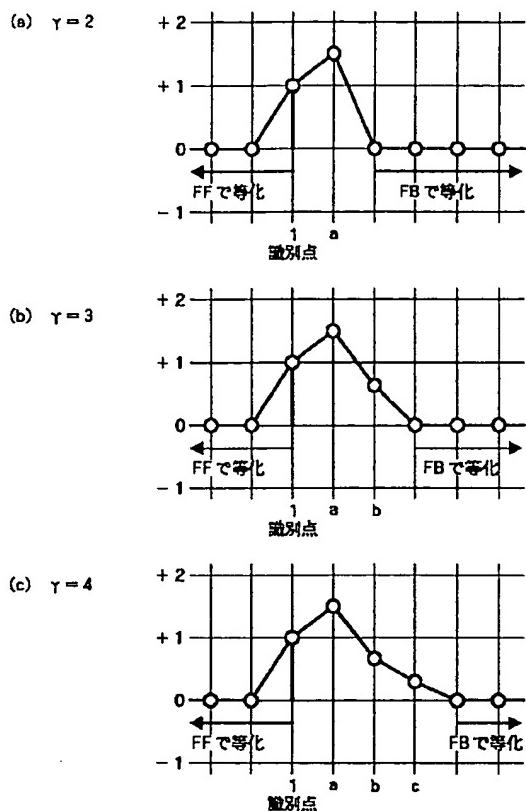
【図8】図1のACS回路2において、 $\gamma=3$ とした場合のメトリック計算式を示す図

【図9】本発明の他の構成における、 $\gamma=3$ での比較器3の構成を示す図

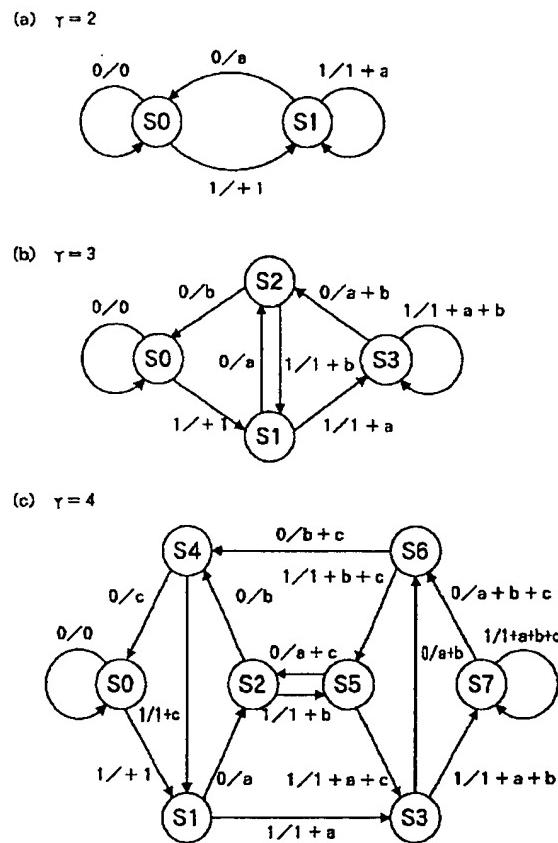
【図10】本発明の他の構成における、 $\gamma=3$ でのバスメモリ4とセレクタ5の構成を示す図

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【図2】

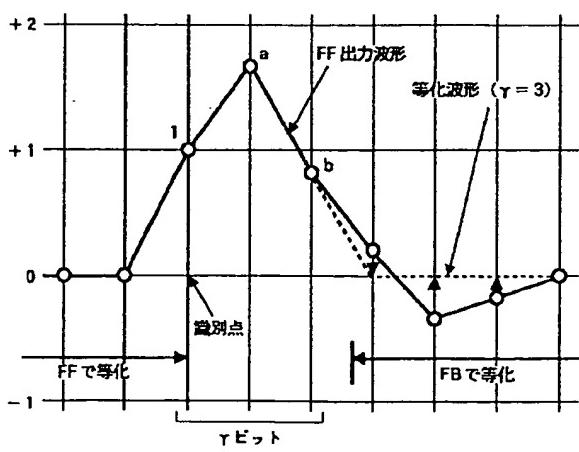


【図3】

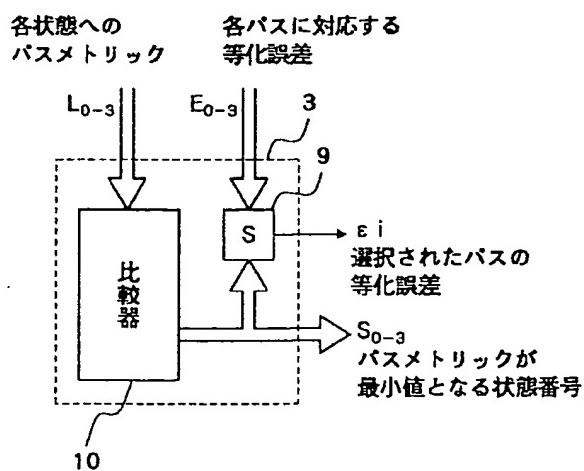


検出データ／等化基準地  
 $\gamma$  : フリー深さ  
a, b, c : インパルス応答波形の出力値 (図2参照)

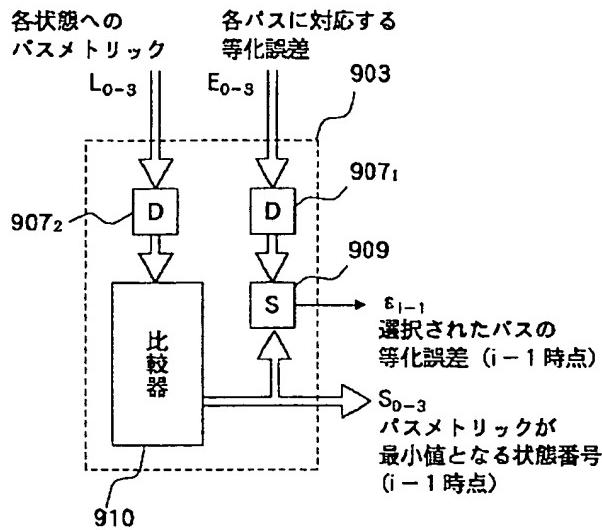
【図4】



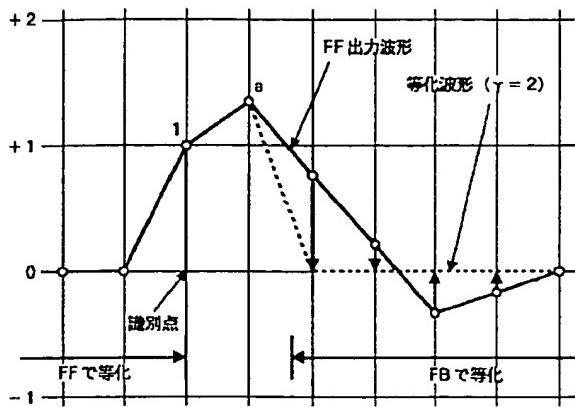
【図5】



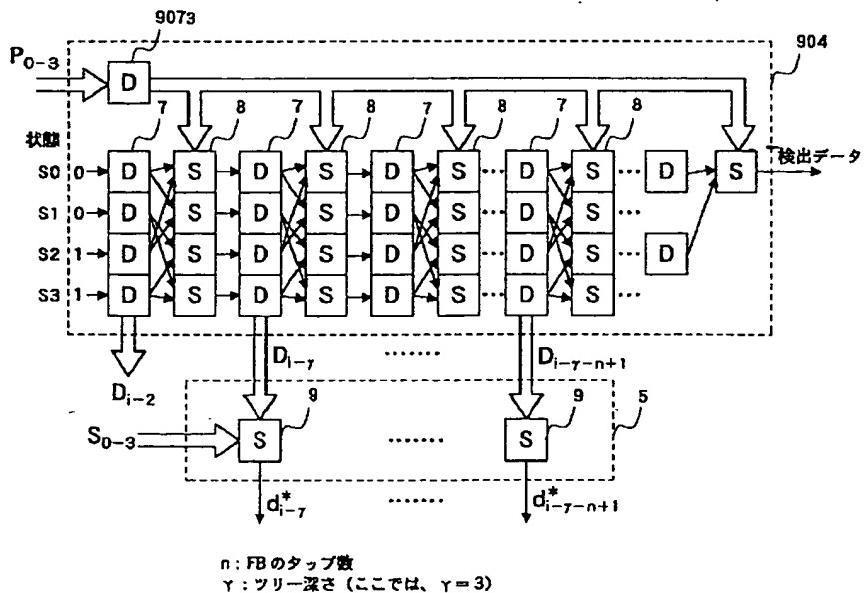
〔図9〕



[図13]



【図10】



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